Southwest Fisheries Center Adminstrative Report H-83-2C

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U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
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THE EARLY LIFE HISTORY OF MAHIMAHI (CORYPHAENA HIPPURUS AND C. EQUISELIS) AND SKIPJACK TUNA (KATSUWONUS PELAMIS): A REPORT ON THE CULTURE AND GROWTH OF LARVAL FISH REARED IN THE LABORATORY

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A Final Report Fulfilling Requirements of a
National Marine Fisheries Service Contract
(Purchase Order No. 82-ABA-305)

March 1983

NOT FOR PUBLICATION

PREFACE

This report was prepared under contract (Purchase Order No. 82-ABA-305) by Sharon D. Hendrix, graduate student, University of Hawaii. The contract objectives were to collect and analyze data on the effects of various diets and rearing conditions on growth and survival of mahimahi (*Coryphaena hippurus* and *C. equiselis*) and skipjack tuna (*Katsuwonus pelamis*) larvae reared under laboratory conditions. These data will provide information and insight on the early life histories of these commercially valuable species. The data will also provide a guide for future studies such as those designed to measure the effects of normal environmental fluctuations and pollutants on survival and growth of these fish species' larvae in the wild. Since the report has been prepared under contract, the statements, findings, conclusions, and recommendations herein are those of the contractor and do not necessarily reflect the view of the National Marine Fisheries Service.

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March 4, 1983

The early life history of mahimahi (*Coryphaena hippurus* and *C. equiselis*) and skipjack tuna (*Katsuwonus pelamis*): A report on the culture and growth of larval fish reared in the laboratory.

INTRODUCTION

Laboratory culture techniques have been developed that enable scientists to obtain information on the early life history of tropical pelagic marine fishes that is not possible to obtain using sea-caught larvae. This type of information is valuable for the understanding of the ecology of tropical pelagic larval fish as well as for the potential aquaculture of these species. This report summarizes studies of the growth, development, behavior, mortality and condition of larval skipjack tuna (*Katsuwonus pelamis*) and mahimahi (*Coryphaena hippurus* and *C. equiselis*) reared in controlled laboratory conditions. The objective of this study was to compare growth and survivorship of mahimahi and skipjack tuna larvae reared in the laboratory under different culture techniques and diets.

MATERIALS AND METHODS

This work was completed during 1982 at the Kewalo Research Facility of the National Marine Fisheries Service Honolulu Laboratory (KRF). Mahimahi were cultured from March - May and August - October, and skipjack tuna were cultured from June - August when spawning adult skipjack tuna were available. Mahimahi (C. hippurus) eggs were obtained from captive spawning adults held at KRF, the Oceanic Institute (Makapuu Pt.), and the Waikiki Aquarium. Eggs were spawned and fertilized naturally, without hormone or stress inducement. C. equiselis eggs were obtained from naturally spawning adult broodstock maintained at the Waikiki Aquarium. Skipjack tuna eggs were obtained at KRF by stress induced spawning of newly captured adult skipjack tuna (Kaya etal, 1982). Mean egg diameters for skipjack tuna and mahimahi were determined by measuring the diameters of of 25 eggs sampled from each spawn. Skipjack tuna eggs were shipped to Kinki University in Japan, and to NMFS-SWFC La Jolla laboratory for coordinated rearing experiments among these three laboratories.

Skipjack tuna eggs were stocked into rearing tanks at a density of 15 eggs/liter, mahimahi eggs at 10 eggs/liter. Rearing tanks were cylindrical black fiberglass tanks with volume maintained at 300 liters (diameter = 1.22 m, water depth = 24 cm). Smaller cylindrical black fiberglass vessels were used for food selection experiments (volume = 25-30 l, diameter = 40 cm). Fluorescent lamps suspended over the tanks provided illumination of approximately 6 x 10 μwatt /cm at the surface. Rearing tanks were fitted with a 1 cm grid at the bottom that was used for behavioral work as well as density estimates. Rearing tanks were initially filled with 300 liters of UV sterilized or 0.22 μm millipore filtered seawater. Volume was maintained at 300 liters by a constant level siphon (Houde, 1972). Daily additions of the diatom Chaetoceros (4-8 liters/day of dense culture) helped to maintain water quality (Mayo, 1973; Houde, 1972; Hassler and Rainville, 1975). Each day, water was siphoned from the tank bottoms to remove dead larvae and prey organisms. Usually, 10-20% of the total tank volume was exchanged each day, by replacing the siphoned water with freshly filtered seawater and algae.

Mahimahi eggs and yolk sac larvae were subjected to moderate aeration, which was decreased upon intiation of feeding behavior. Skipjack tuna eggs and larvae were subjected to gentle or no aeration. Mahimahi were also reared in outdoor conditions. The tanks were exposed to indirect sunlight and water temperatures ranged from 25-29°C. Temperature in the indoor rearing tanks ranged from 21-24°C.

Larval culture

Mahimahi and skipjack tuna larvae were initially fed laboratory cultures of rotifers (*Brachionus plicatilis*) and/or harpacticoid copepods (*Euterpina acutifrons*). These prey organisms were stocked at a density of 5-10 organisms/ml. As larvae grew, they were fed progressively larger prey, such as *Artemia salina* nauplii (or larger stages of *Artemia* when required), laboratory cultured harpacticoid copepods (*Tigriopus* sp.) and mahimahi yolk sac larvae. Large mahimahi larvae (approximately 2-3 cm standard length,> 25 days old) were fed mollies and diced squid. Juvenile mahimahi were transferred to large (2.43 and 7.3 m diameter), outdoor tanks supplied with circulating seawater.

Growth rates were determined by sampling 10 or more larvae periodically, but fewer larvae were sampled as the numbers of larvae in a tank population declined. Standard Length (SL), eye diameter, head depth, yolk sac length and width, and oil globule diameter were measured while larvae were alive, using a calibrated micrometer mounted in a dissecting microscope. Bodies were saved in either 3% buffered formalin or 80% ethanol.

Behavioral observations were made daily if possible, noting feeding behavior and swimming speed. Swimming speeds were determined by counting the number of 1 cm grid crossings made by a larva over time, and taking the mean of 10-12 observations per day (observation times were >10 seconds in length). During swimming speed observations, the number of feeding strikes made by each larva (successful and unsuccessful) was noted.

Food selection

Food selection experiments were conducted on C. equiselis and C. hippurus. Eggs were stocked in small rearing vessels at a density of 15 eggs/liter. Food organisms were distributed to the rearing vessels as follows;

1. Rotifers, (B. plicatilis), 5/ml,
2. Rotifers, 2.5/ml + copepods, (Tigriopus sp.), 2.5/ml,
3. Copepods, (Tigriopus sp.), 5/ml,
4. Starvation.

As a further control, a large 300 liter rearing tank was also used; larvae reared in this tank were given rotifers as food organisms. Food selection was determined by allowing larvae to feed for a 1 hr period (larvae feed visually, so a 1 hr feeding period is equivalent to the first hour of light), and then sampling 20 larvae for stomach analysis and growth determinations. Bodies were saved in 80% ethanol for future otilith studies. Food Selectivity was determined (Strauss, 1979) and mortality records were kept. Feeding selectivity experiments were conducted daily upon larvae died or day 10, whichever came first. Behavioral observations were made only for larvae reared in the 300 liter tanks, due to difficulty observing larvae in the small vessels. 7

RESULTS

General observations

Skipjack tuna larvae are difficult to culture. However, the 1982 efforts resulted in rearing of skipjack tuna from hatching to metamorphosis (up to day 35) at NMFS La Jolla (S. Kaupp, pers. comm.). Skipjack tuna were successfully cultured for 7 days at KRF and 15 days at Kinki University in Japan (T. Harada, pers. comm.). C. hippurus larvae were successfully reared through metamorphosis to approximately day 191 when the fish were lost due to rupture of their holding tank). Only one attempt was made to rear C. equiselis, the larvae survived through day 8.

Both skipjack tuna and mahimahi eggs are spherical and transparent. Skipjack tuna eggs ranged from 0.889 to 0.982 mm in diameter, while C. hippurus eggs were 1.52-1.66 mm in diameter, and C. equiselis eggs were approximately 1.4 mm in diameter. At hatching, skipjack tuna larvae averaged 2.9-3.0 mm in length with a yolk sac ranging from 0.78 to 1.03 mm in length and 0.52 to 0.66 mm in width. C. hippurus larvae at hatching averaged 4.3 to 5.4 mm in length with a yolk sac ranging from 1.54 to 1.85 mm in length and 0.39 to 0.47 mm in width and an oil globule of 0.31 to 0.34 mm in diameter. 8-67% of skipjack tuna and mahimahi larvae were observed to have been deformed at first feeding (usually jaw and head abnormalities), presumably due to poor egg quality.

At hatching, skipjack tuna larvae were nearly transparent and had very little pigmentation through day 12. By comparison, mahimahi were transparent at hatching but became darkly pigmented by day 2. Mahimahi yolk sac larvae (up until day 2), were much like skipjack tuna larvae in that they were nearly transparent and tended to float near the surface in a head down position, essentially motionless, except for occasional bursts of swimming.

At day 2, mahimahi larvae tended to orient near the bottom of the tanks, with very few larvae remaining in the upper half of the water column. Larvae that settled to the tank bottom tended to become fouled by bacteria, hence tank water needed to be agitated in order to prevent mahimahi larvae from remaining on the bottom.

Generally, mahimahi larvae had pigmented eyes and functional jaws and stomachs by day 3.

At day 3, mahimahi larvae were oriented near the surface and swam horizontally, usually feeding. Skipjack tuna larvae tended to remain bouyant throughout the yolk sac period and into first feeding. Eyes became pigmented, and stomachs and jaws functional by day 3.

Mahimahi larvae exhibited marked variation in pigmentation on day 4, coloration varyed from light yellow to dark brown. The lightly colored larvae demonstrated a tendency to feed more actively and appeared more robust than did the dark larvae. In adult mahimahi, stressed fish become very darkly pigmented, especially at capture and near death. This coloration response may also apply to mahimahi larvae. Larvae of both skipjack tuna (S. Kaupp, pers. comm.) and mahimahi metamorphosed by day 35 and were piscivorous (able to feed on other fish larvae) by day 25 (S. Kaupp, pers. comm.). Cannabalism was not observed in either larval skipjack tuna or mahimahi within a brood.

Growth

Selected growth data are summarized for skipjack tuna larvae in table 1 and for both species of mahimahi in table 2. Skipjack tuna larvae reared at KRF did not exhibit significant growth. However, growth was significant for larvae reared at NMFS La Jolla laboratory, with one larva reaching a length of 39.5 mm on day 35 (S. Kaupp, pers. comm.). Skipjack tuna larvae reared at La Jolla grew in spurts, larvae grew rapidly with each addition of larger prey types (ie. rotifers, copepods, yolk sac larvae) and grew better when the dinoflagellate Tahitian *Isochrisis* was added to the rearing vessel (S. Kaupp, pers. comm.). At day 34, the last surviving cultured skipjack tuna larva ingested 40 to 50 10-12 mm halibut larvae, representing a substantial energy intake (S. Kaupp, pers. comm.). The larva died due to unforeseen circumstances. ?

The effect of temperature on growth of mahimahi (*C. hippurus*) is seen in figure 1. Growth at 26.2°C and 22.8°C was comparable up until day 12, when there was a rapid acceleration in growth of larvae reared at 26.2°C (fig. 1). Corresponding trends in growth with temperature are seen for head depth and eye diameter (figs. 2 and 3). Mahimahi larvae reared at 26.2°C grew at nearly the same rate as mahimahi reared at 27°C (Hassler and Rainville, 1975; Palko etal, 1982). Growth of head depth and eye diameter varied linearly with length (figs. 4 and 5). Linear equations were fit to data describing growth of mahimahi reared at 26.2°C as seen in fig. 4.

Results obtained from food selection experiments did not demonstrate any effect of diet on growth. Cultures of E. acutifrons were not available for these selection experiments, therefore Tigriopus sp. was used as a prey organism with rotifers. Tigriopus is a large harpacticoid copepod with demersal nauplii, and thus, Tigriopus are not good prey for first feeding larvae. Indeed, no larvae reared on Tigriopus survived beyond day 6. Therefore, growth data are taken only from feeding experiments using rotifers as prey. The length-age plot for the first ten days of growth of mahimahi larvae (C. hippurus) was nonlinear (fig. 6).

The growth of mahimahi was modeled by two generalized equations which describe significant events in early larval growth. The first equation describes growth from hatching through yolk absorption and first feeding. During this period, larvae approached an asymptotic length between days 2 and 6 (fig.6). This asymptotic function may best describe growth in length, but conceivably growth described by other parameters such as dry weight or calories may not demonstrate the same trend. After significant mortalities on days 6-7, surviving larvae initiated exponential growth. The generalized equations of this model are:

$$L_t = \begin{cases} \lambda(1 - \theta e^{-\gamma t}) & ; \quad 0 \le t \le \tau \\ \lambda(1 - \theta e^{-\gamma \tau}) \left(\frac{t}{\tau}\right)^{\beta} & ; \quad t > \tau \end{cases}$$

where L_t = length at age t;

λ = asymptotic length approached b first feeding larvae before exponential growth comm ces;

$\lambda(1 - \theta)$ = length at $t = 0$;

τ = transition between growth stages;

γ = rate of growth when $0 < t < \tau$;

β = rate of growth when $t > \tau$.

Estimated parameters are given in table 3 for growth data presented in fig. 6. This is a general growth model describing larval *C. hippurus* but should be applicable to early growth of other species of larval fish (Hunter, 1976). Again, larval growth was linear with respect to head depth, eye diameter and length (figs. 7 and 8).

Differences in growth due to starvation are not apparent until day 5 (table 4). By day 6, starved larvae have significantly smaller eye diameters and are shorter than fed larvae, but head depths are not significantly different (table 4).

Mortality

Skipjack tuna larvae reared at KRF tended to have very heavy mortality with most larvae dying or dead by day 4. A similar mortality trend was seen in starvation experiments on larval pacific mackerel (Hunter and Kimbrell, 1980), and mahimahi reared at KRF, where starved larvae began to die on day 4 and were all dead by day 7. Both species of mahimahi raised at KRF generally exhibited less than 5% mortality per day from hatching through day 5. On days 6 and 7, larvae suffered higher mortality rates of between 7-63% per day (fig. 9). Few of the skipjack tuna larvae successfully initiated feeding. Less than 50% of the larvae sampled on day 3 had any food present in their stomachs. Even so, there is evidence that larvae selected Euterpina nauplii over rotifers when given a choice, and larvae generally ingested larger proportions of copepod nauplii than were available as prey in the environment (fig 10). Sea-caught skipjack tuna larvae from the Hawaii region usually have only larvaceans or the cyclopoid copepod Corycaeus sp. in their stomachs, perhaps indicating a strong selection for these prey types (Uotani etal, 1981; and pers. obs.). We suspected that egg size may influence the length of larvae at hatching and the amount of yolk reserves available to the larvae. Smaller eggs could result in an energetic deficiency because they have a smaller amount of available yolk. A comparison was made of larvae reared from 2 spawns with different mean ova diameters (table 5). No significant effect of ova diameter was found on larvae from hatching through first feeding (table 5).

Initial feeding experiments on C. hippurus indicate a tendency for larvae to select for Euterpina copepods from first feeding through day 7 when presented a diet of both rotifers and copepods (fig. 11, table 6). Rotifer fed larvae did not have a tendency to select to either gravid or nongravid rotifers (fig. 12, table 7). Tigriopus-fed mahimahi larvae (both C. equiselis and C. hippurus), tended to ingest only Tigriopus fecal pellets. As mentioned earlier, Tigriopus are not adequate prey for first feeding larvae due to inaccessibility of small naupliar stages. Fecal pellets are approximately 60 x 110 μm in size and are probably easily ingested by mahimahi larvae.

No trends were seen in swimming speeds of mahimahi larvae from first feeding to day 10, however increases in feeding strike frequency were shown (fig. 13). Mahimahi and skipjack tuna larvae demonstrated typical larval scombrid feeding behavior (Hunter, 1980; Hassler and Rainville, 1975). A larva would sight a prey organism, draw its tail back so that its body was in a tight "s" or "j" curve, and then strike and ingest the prey. Observations of mahimahi indicated that a larva would not always strike a prey item, even if the larva coiled its body into an "s" curve. This behavior is noted as "abandoned strikes" in fig. 13. Ten day old larvae had a smaller proportion of abandoned strikes than 7 day old larvae (fig. 13). When mahimahi were large enough to feed on other yolk sac larvae, these prey were usually engulfed with little or no handling time; ingestion was quick and efficient.

Mahimahi larvae started "rafting" behavior around day 20. This involved orienting and maintaining a position under or relative to stationary items such as airline tubing. This type of behavior is frequently seen in adult mahimahi (Hunter and Mitchell, 1967).

DISCUSSION AND RECOMMENDATION

This years efforts to rear skipjack tuna were promising, with larvae cultured through metamorphosis. Even so, skipjack tuna are difficult to rear and exhibit very low survivorship (Mayo, 1973;Uyenagi etal, 1974; Inuoe etal, 1974; Houde and Richards, 1969). The results obtained indicate an overall poor egg quality, especially since mortality was so high during yolk sac stages and deformities were so common. Poor maternal investment due to stress induced spawning could possibly have caused the deformities and high mortalities. However skipjack tuna can be reared to metamorphosis successfully, which suggests other causative factors.

Diet is very critical to larval survival. Results from rearing skipjack tuna in La Jolla indicate that larval growth may have been reduced by the inability of the larvae to consume sufficient energy to meet the demands of rapid development (S. Kaupp, pers. comm.). For future research on skipjack tuna, I recommend the following:

1. Rear skipjack tuna from naturally spawned eggs obtained from

plankton tows to see if stress induced ovulation effects egg quality and to test rearing techniques.

2. Continue work on diet to obtain optimal prey types, focus on energy demands of larvae and caloric content of prey. Rear skipjack tuna larvae on wild plankton, especially larvaceans and Corycaeus sp. (these prey species are found in the diets of sea-caught larvae). Continue work on stomach analysis of sea-caught skipjack tuna larvae to determine other optimal foods.

Both skipjack tuna and mahimahi demonstrate rapid growth rates, and require large quantities of food for growth and maintenance (Mayo, 1973). Mahimahi appear to be a hardier species than skipjack tuna. Pigmentation occurs very early in mahimahi development, suggesting that mahimahi larvae may live near the surface while skipjack have been found at depths of 20 meters (Sund etal, 1981). The observation that mahimahi larvae will ingest fecal pellets is important in several aspects. It is unknown if they ingest fecal pellets in their natural environment. If mahimahi larvae will ingest inanimate objects such as fecal pellets,it raises the question: can mahimahi be aquacultured on artificial diets from first feeding?

Abandonment of feeding strikes is another ecologically interesting phenomena. Why should a mahimahi larva abandon a prey once it is sighted and strike position is attained? Here is an example of potential energy waste, since the larva abandons or loses its prey and must search for another. Perhaps the best explaination for this phenomena is that the prey item swims out of the effective visual range of the mahimahi larva after the larva has achieved strike position. Another possible explanation is that the larva may actually abandon a prey item because the prey is unsuitable due to incorrect size or type.

Mahimahi represent an excellent species to use as a model for growth and condition of larval fishes. The obvious effect of diet and food selection on growth should be seen in the growth function (or second equation) of the 5 parameter model presented in this report. The rate of acceleration of growth after day 6 should reflect the condition of the larvae, healthier larvae should grow faster. This potential variation in growth rate may be reflected in otolith increment width, which would be useful as a criterion for larval fish condition in the sea (Hunter, 1976; Methot, 1979).

I recommend continued work on larval mahimahi (especially C. hippurus) with the following studies:

1. Continue food selection studies and attempt to determine if a criterion for larval condition (otolith increment width) can be established.

2. Use mahimahi as a model for improving culture techniques applicable to skipjack tuna larvae. Optimize culture techniques, experiment with temperature effects, effects of hormones such as thyroxine, and effects of various prey types (including effects of different algal species as the primary step in the food chain) on larval growth and survival. If possible, conduct stomach analysis on sea-caught mahimahi larvae.

ACKNOWLEDGEMENTS

Richard Brill, Thomas Kazama, Sidney Kraul, James Szyper, and Bob Bourke for support and collaboration. Jerry Wetheral and Christopher Boggs for statistical assistance. Linda Barraclough for technical assistance. Jeffrey Corwin, Michael Hadfield, Stephen Ralston, and William Barnett for comments and advice. Sandor Kaupp for rearing skipjack tuna through metamorphosis and for continual feedback and guidance.

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Table 1: Summary of growth and survivorship from 1982 rearing experiments on skipjack tuna larvae (*Katsuwonus pelamis*).
Number of larvae sampled, mean length ($\bar{x}$) and standard deviation (SD) in mm are given with information on spawn date, tank identification, feeding conditions and mean temperature $\pm$ 1 SD (°C)

	16 June 82 Tank A Rotifers 23.76°C±0.57			20 June 82 Tank B Euterpina 23.63°C±1.00			28 June 82 Tank B Euterpina 23.45°C±0.36			6 July 82 Tank C Mix* 24.17°C±0.72			31 July 82 TankC Mix 24.3°C±0.63			31 July 82 La Jolla mix		
Age (days)	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD
0	12	3.34	0.194	12	2.83	0.256	12	3.22	0.195	12	2.94	0.230	12	2.87	0.249	8	2.19	0.215
1	12	3.34	0.194				12	3.38	0.153									
2				12	3.65	0.081												
3				12	3.592	0.155	12	3.59	0.153	12	3.54	0.135	12	3.68	0.127	12	3.57	0.084
4	12	3.30	0.129															
5	12	3.36	0.184	1	3.35					10	3.69	0.076	12	4.03	0.227			
6	2	3.55	0.141							4	3.73	0.087						
7										2	4.20	0.283						
8																		
9																		
10																		
11																		
12																1	4.80	
13																		
14																		
15																		
16																1	8.20	
17																		
18																4	8.75	
//																//		
35																1	39.50	

*Mix=rotifers + Euterpina
or fotifers + Tigriopus

Table 2: Summary of growth and survivorship from selected 1982 rearing experiments on mahimahi larvae (Coryphaena hippurus and C. equiselis). Number of larvae sampled, mean length ($\bar{x}$) and standard deviation (SD) in mm are given with information on spawn date, tank identification, feeding conditions and mean temperature $\pm$ 1 SD (°C)

	4 May 82 Tank B Mix * 22.82°C±0.387 C. hippurus			6 May 82 Tank D Mix 26.26°C±0.427 C. hippurus			15 October 82 Tank C Rotifers 22.89°C±1.043 C. hippurus			15 October 82 Pot D starved 21.95°C±0.554 C. hippurus			17 October 82 Pot I Rotifers 22.78°C±0.172 C. equiselis		
Age (days)	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD
0	15	4.87	0.265												
1	15	5.37	0.187				20	4.96	0.135						
2	15	5.40	0.177				20	5.27	0.128						
3	10	5.56	0.119	12	5.30	0.165	20	5.34	0.106	20	5.15	0.256	20	5.33	0.087
4							20	5.39	0.094	20	5.34	0.061	20	5.42	0.188
5	12	5.50	0.104	10	5.62	0.303	20	5.39	0.106	20	5.29	0.113	20	5.56	0.090
6							20	5.54	0.178	20	5.36	0.087	20	5.52	0.152
7	10	5.75	0.486	5	6.13	0.406	20	5.84	0.238	5	4.80	0.169	20	5.57	0.198
8							20	5.98	0.225				11	5.59	0.178
9	5	6.38	0.177	3	6.50	0.361	20	6.26	0.266						
10				3	6.40	0.492	20	6.70	0.142						
11	1	6.90		1	7.25										
12	1	6.90					14	6.99	0.556						
13				3	7.88	0.480									
14															
15	2	7.95		2	8.68	0.742									
16				1	8.10										
17				1	11.2										
18	1	11.2		2	15.3	1.69									
19	3	8.8	0.888												
20	1	10.2													
21	2	10.6													
22															
23	1	7.0													
24	2	12.75													
//				//											
28				2	28.7										

4 and 6 May 82
8' and 24' tanks
C. hippurus juveniles

Day	$\bar{x}$	SD
62	184.0	
132	383.0	
167	396.0	
191	535.0	38.22

*Mix=rotifers + Euterpina or Tigriopus

Table 3: Estimated parameters for the model describing the growth of mahimahi (*C. hippurus*) larvae spawned on 15 October 1982.

PARAMETER	ESTIMATE	ASYMPTOTIC STD. ERROR	ASYMPTOTIC 95% CONFIDENCE INTERVAL	
			LOWER	UPPER
THETA	0.26169	0.07891	0.06859	0.45480
LAMBDA	5.39764	0.02551	5.33520	5.46006
TAU	5.51097	0.17353	5.08634	5.93560
GAMMA	1.16619	0.30249	0.42604	1.90636
BETA	0.31923	0.02667	0.25398	0.38449

Table 4: Comparison of starved vs fed mahimahi larvae (*C. hippurus*) from 15 Oct. 82 spawn.

AGE (DAY)	PARAMETER (mm)	STARVED $\bar{x} \pm 1$ SD	FED $\bar{x} \pm 1$ SD	F STAT
Day 4	Length	5.34±0.0614	5.40±0.0743	2.483
	Eye diameter	0.349±0.012	0.342±0.009	4.333
	Head depth	0.780±0.068	0.754±0.058	1.681
Day 5	Length	5.285±0.113	5.48±0.121	27.917
	Eye diameter	0.354±0.009	0.357±0.009	0.978
	Head depth	0.806±0.029	0.790±0.048	1.652
Day 6	Length	5.355±0.087	5.55±0.115	37.609
	Eye diameter	0,355±0.009	0.367±0.012	13.286
	Head depth	0.865±0.064	0.869±0.055	0.0460

Table 5: Comparison of skipjack tuna larvae reared from eggs obtained from different females spawned on 28 June 1982. (note tank B and C have eggs obtained from the same female).

PARAMETER	TANK A $\bar{x}\pm1$ SD	TANK B $\bar{x}\pm1$ SD	TANK C $\bar{x}\pm1$ SD
Ova diameter (mm)	0.94±0.006	0.981±0.015	0.981±0.015
Length at hatch (mm) (n=12)	3.25±0.085	3.221±0.195	3.30±0.182
Length at day 3(mm) (n=12)*	3.617±0.109	3.595±0.153	3.535±0.134
Swimspeed cm/sec	0.3468	0.3921	0.4324
body Length/sec	0.9589	1.090	1.226
#feeding strikes per min	0.1177	0.1069	0.1324
%larvae with food	25%	0%	25%
%larvae without food	75%	100%	75%
# Euterpina nauplii ingested	5	0	3
Temperature (°C)	23.6+0.363	23.45+0.42	23.6+0 35

* data listed below this entry pertain to day 3 larvae

Table 6: Results of initial feeding experiments conducted on mahimahi larvae (C. hippurus) spawned on 6 May, 1982.

LENGTH INTERVAL (mm)	% without food	% with food	TOTAL # LARVAE	RATION #Brachi loricas	#Brachi eggs	Euterpina acutifrons #nauplii	#copepods	#gravid females
5.1-5.5	56	44	16	8	8	63	108	1
5.6-6.0	0	100	5	2	1	38	112	1
6.1-6.5	0	100	7	8	0	140	158	8
6.6-7.0	0	100	4	4	0	134	92	2
7.1-7.5	0	100	1	1	1	27	5	1

Table 7: Results of feeding experiments conducted on mahimahi larvae (*C. hippurus*) spawned on 15 October, 1982.

LENGTH INTERVAL (mm)	%without food	%with food	TOTAL # LARVAE	RATION #Brachi loricas	#Brachi eggs	#Tigriopus nauplii	#Tigriopus copepodites
5.1-5.5	84.85	15.15	66	96	43	0	0
5.6-6.0	41.67	58.33	48	283	64	0	0
6.1-6.5	20.0	80.0	30	253	26	2	0
6.6-7.0	0	100	12	271	9	4	0
7.1-7.5	0	100	4	215	11	0	0

Figure 1: Growth of mahimahi (C. hippurus) reared at 2 different temperatures; 26.2°C ± 0.91°C (+) and 22.8°C ± 0.29°C (·). Points represent individual larvae.

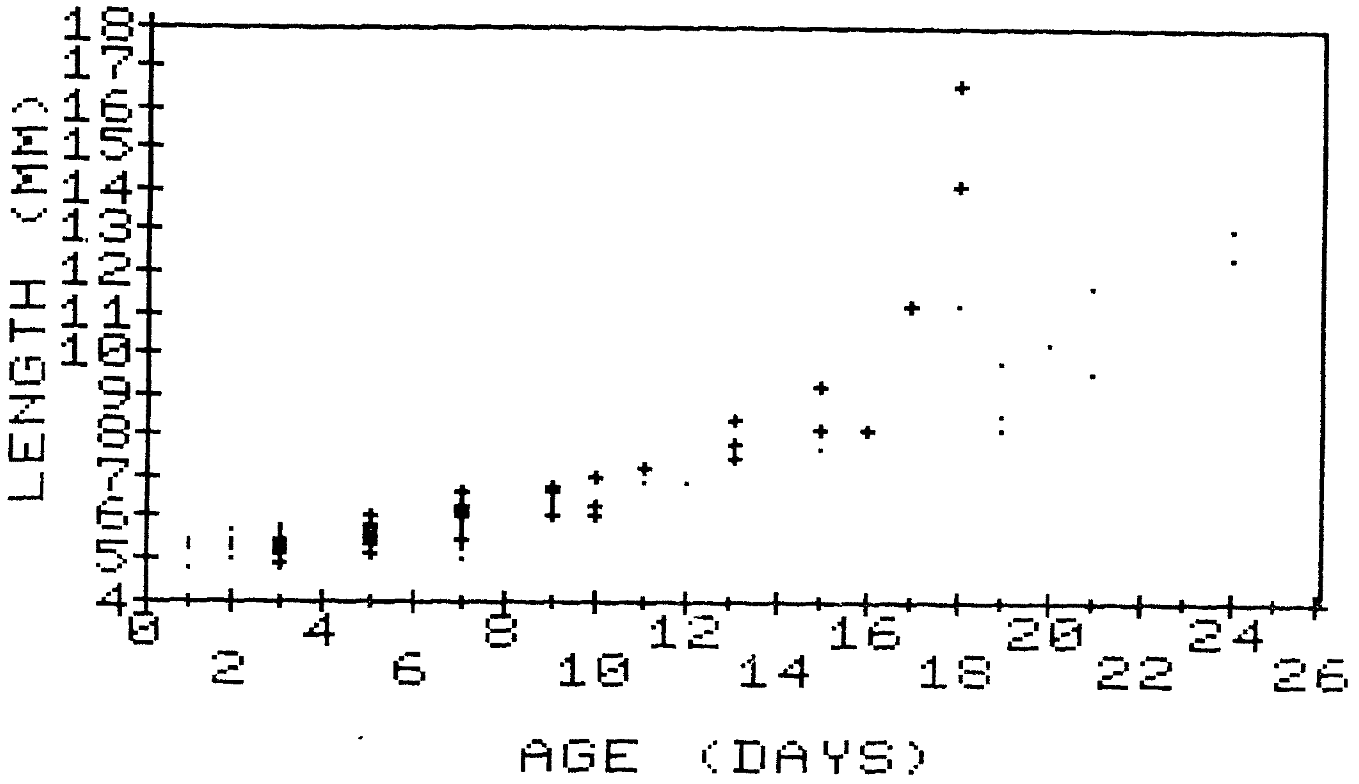

Figure 2: Growth of head depth (□) and eye diameter (+) for mahimahi larvae (*C. hippurus*) reared at 26.2 ± 0.91°C. Points represent indivual larvae.

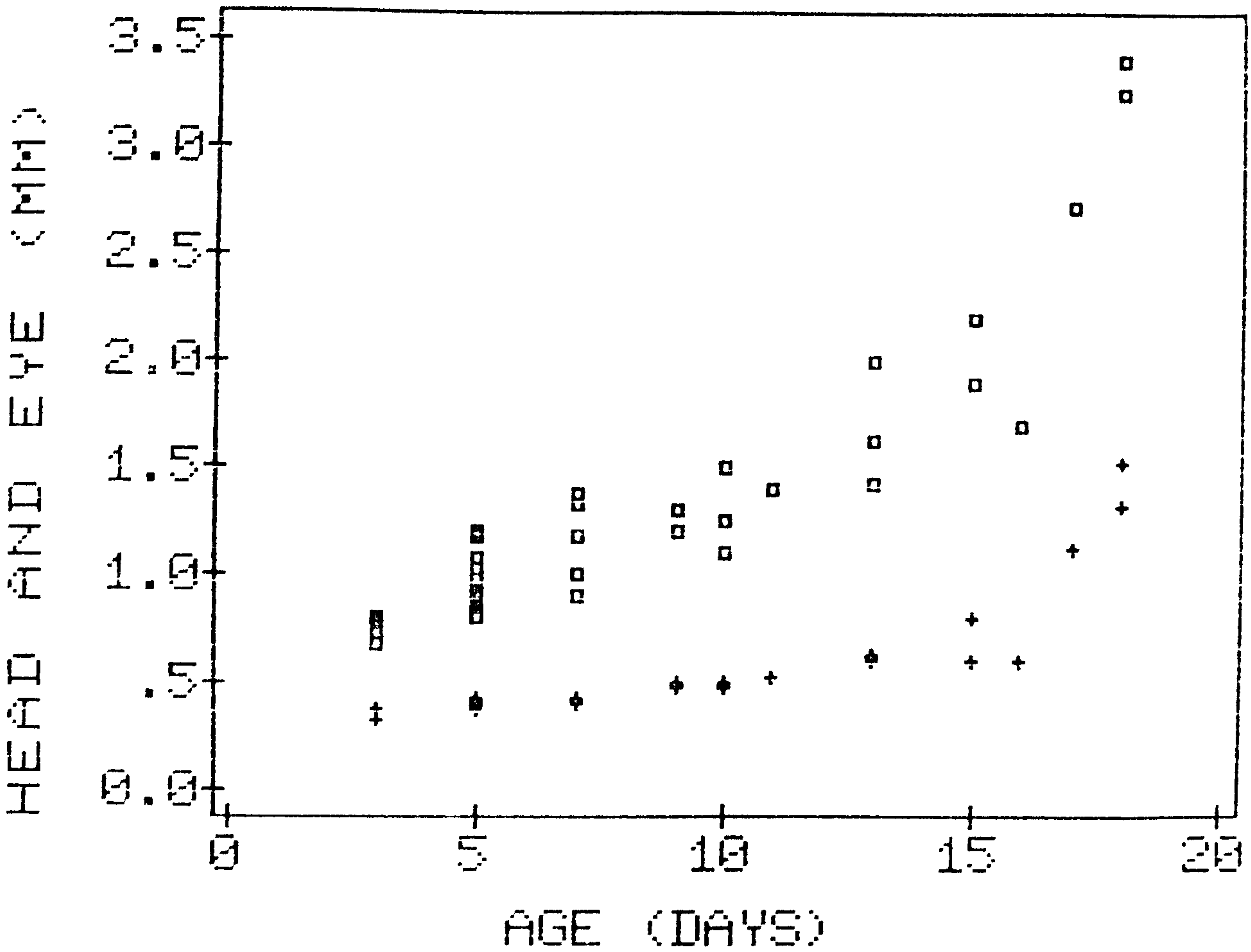

Figure 3: Growth of head depth (□) and eye diameter (+) for mahimahi larvae (C. hippurus) reared at 22.8 ± 0.29°C. Points represent individual larvae.

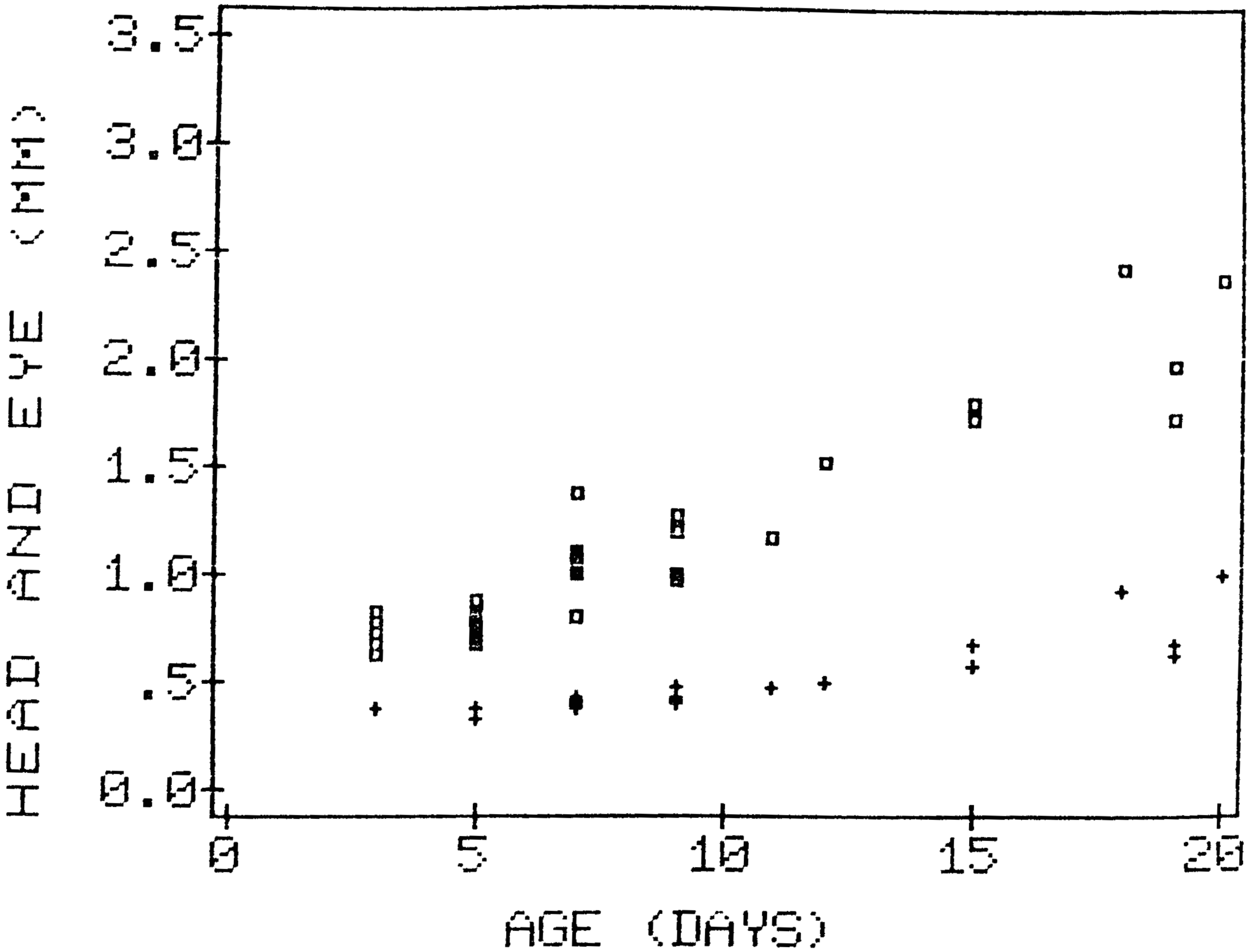

Figure 4: Linear growth of mahimahi larvae (C. hippurus) reared at 26.2±0.91°C. Head depth (□) and eye diameter (+) vs Length. Points represent individual larvae

Head depth=-1.0664 + 0.354 Length, r^2=0.92

Eye diameter=-0.1441 + 0.0949 Length, r^2=0.91

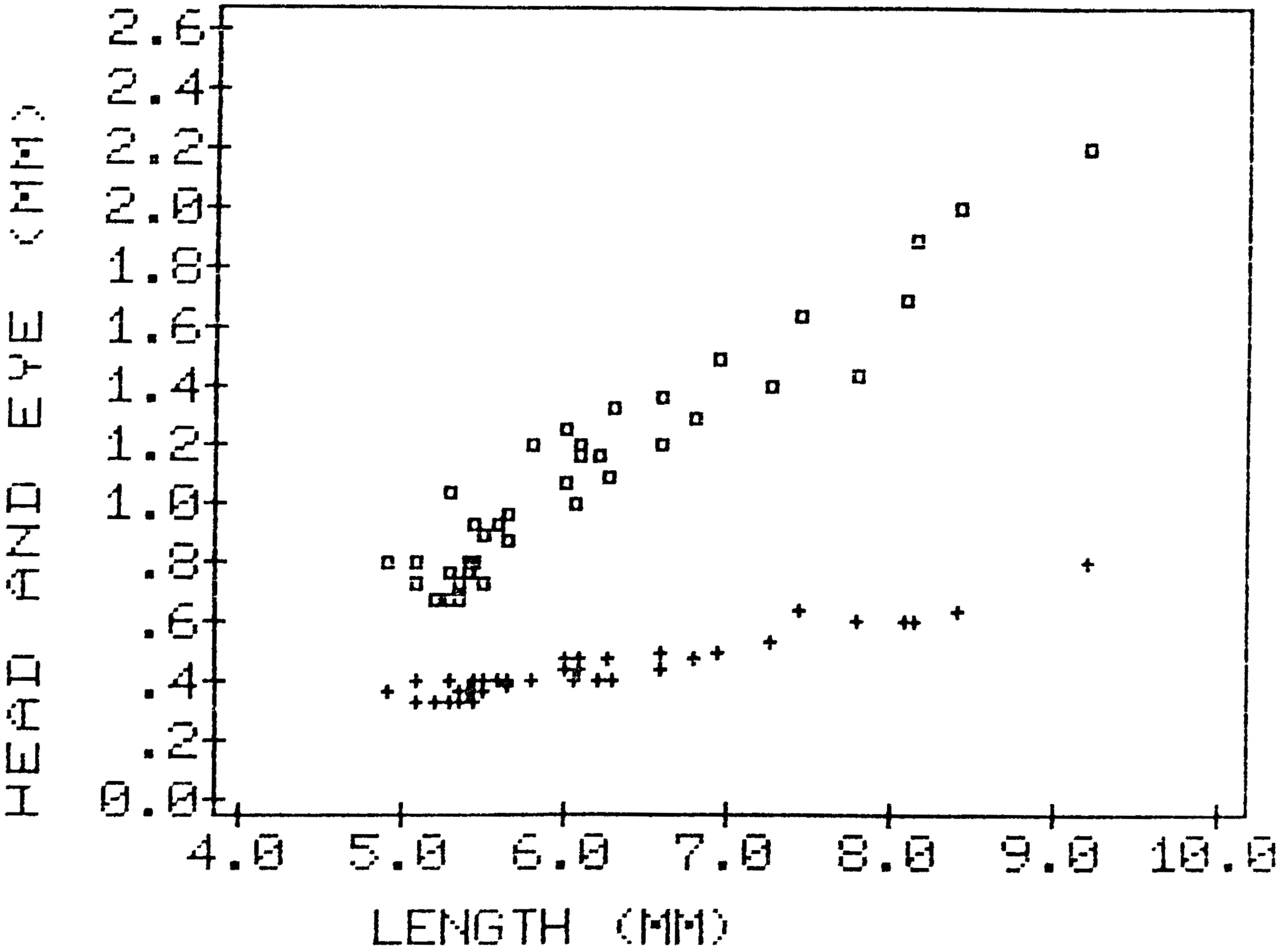

Figure 5: Linear growth of mahimahi larvae (C. hippurus)reared at 22.8±0.29°C. Head depth (□) and eye diameter (+) vs length. Points represent individual larvae.

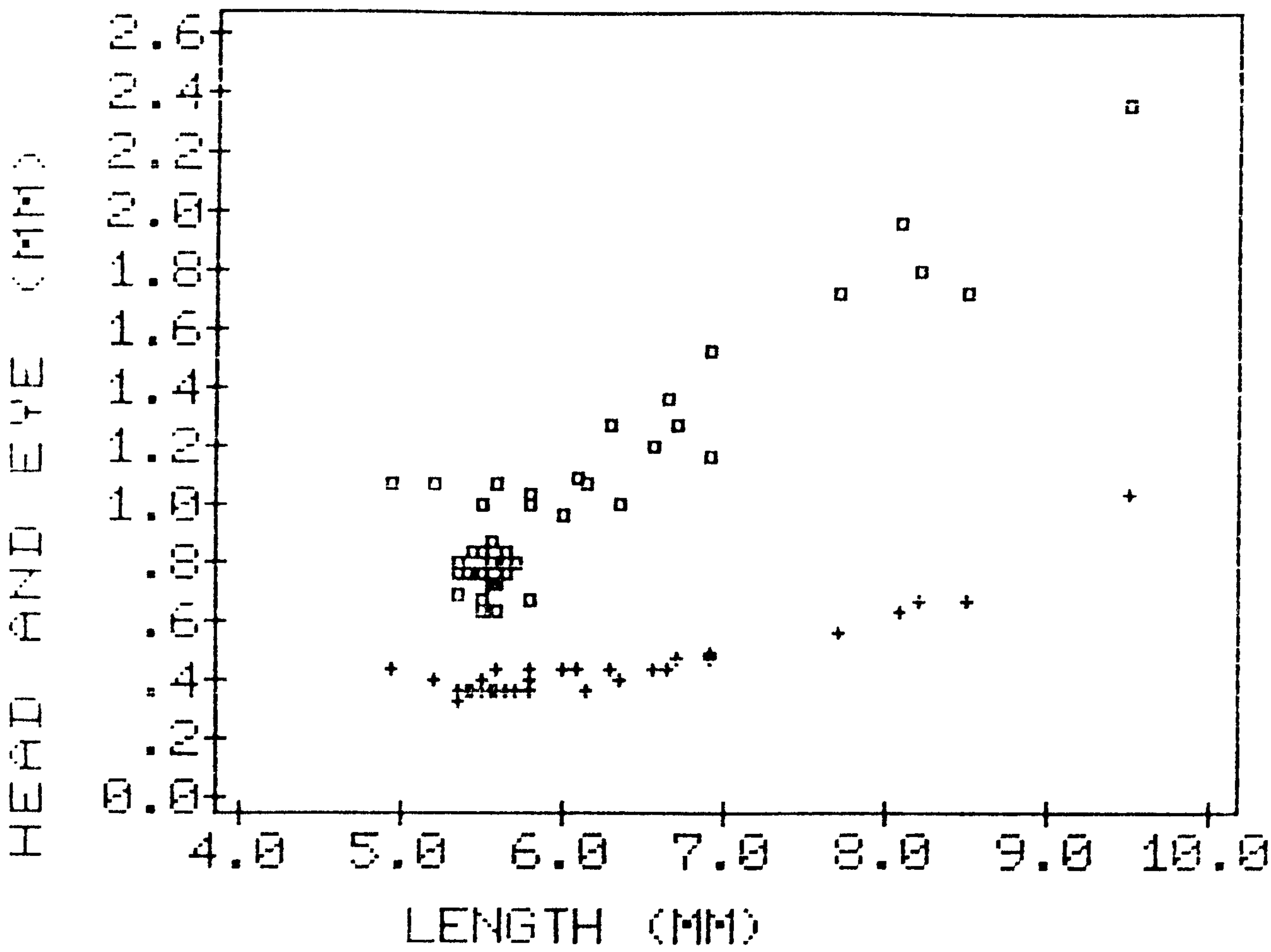

Figure 6: Growth of mahimahi larvae (C. hippurus). Plot is of mean length ± 1 SD of the mean. (data obtained from food selection experiments conducted on 15 Oct. 82 spawn).

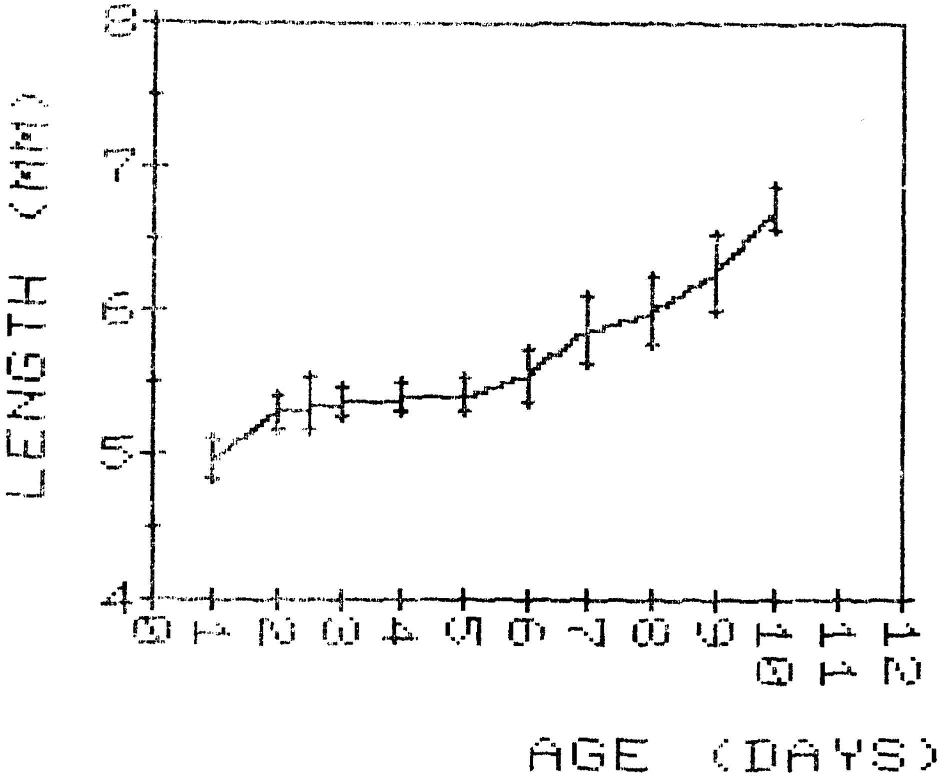

Figure 7: Growth of mahimahi larvae (_C. hippurus_). Plot is of mean head depth (■) and eye diameter (•) ± 1 SD of the mean. (data obtained from food selection experiments conducted on 15 Oct. spawn).

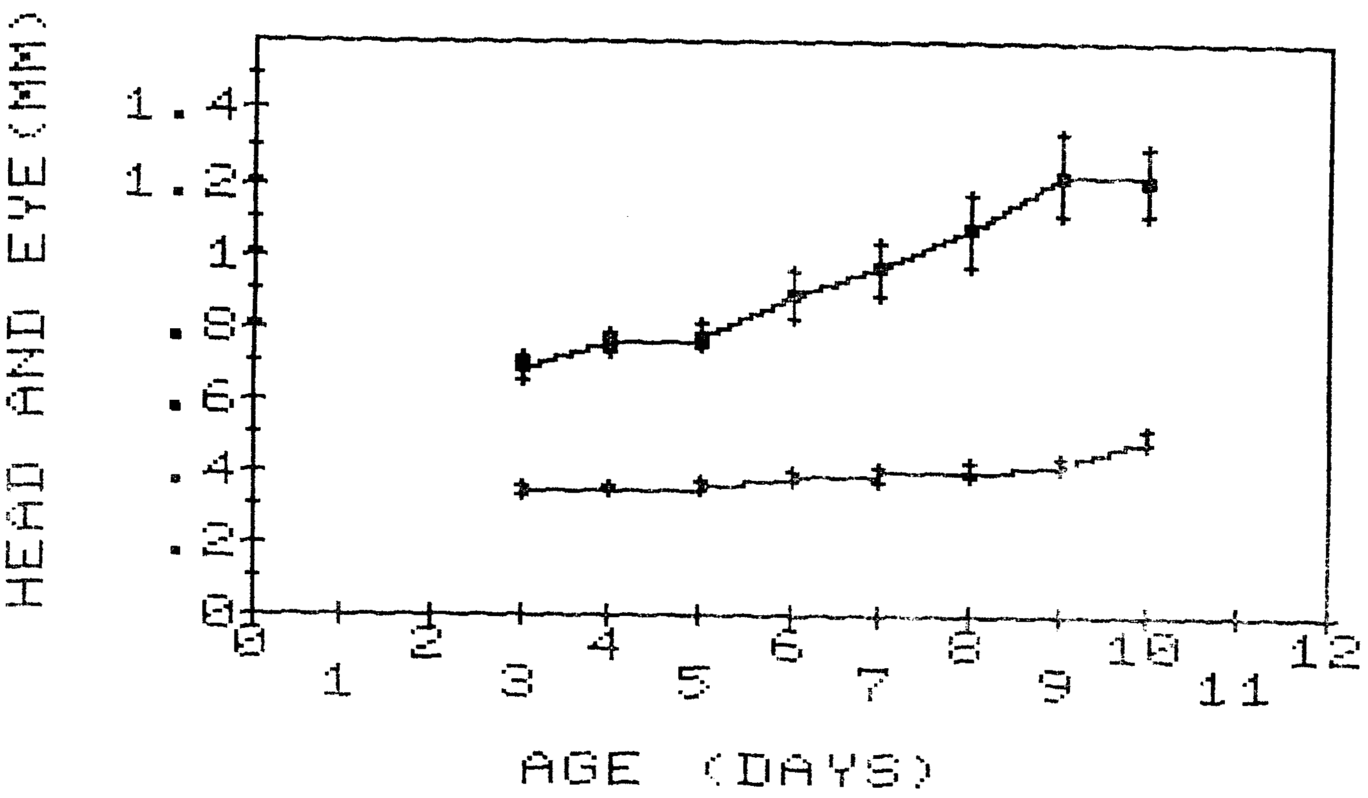

Figure 8: Growth of mahimahi larvae (C. hippurus). Head depth (□) and eye diameter (+) vs Length. Points represent individual larvae. (data obtained from food selection experiments conducted on 15 Oct. spawn).

Head depth=-1.2265 + 0.3739 Length, r^2=0.83

Eye diameter=-0.01994 + 0.06952 Length, r^2=0.84

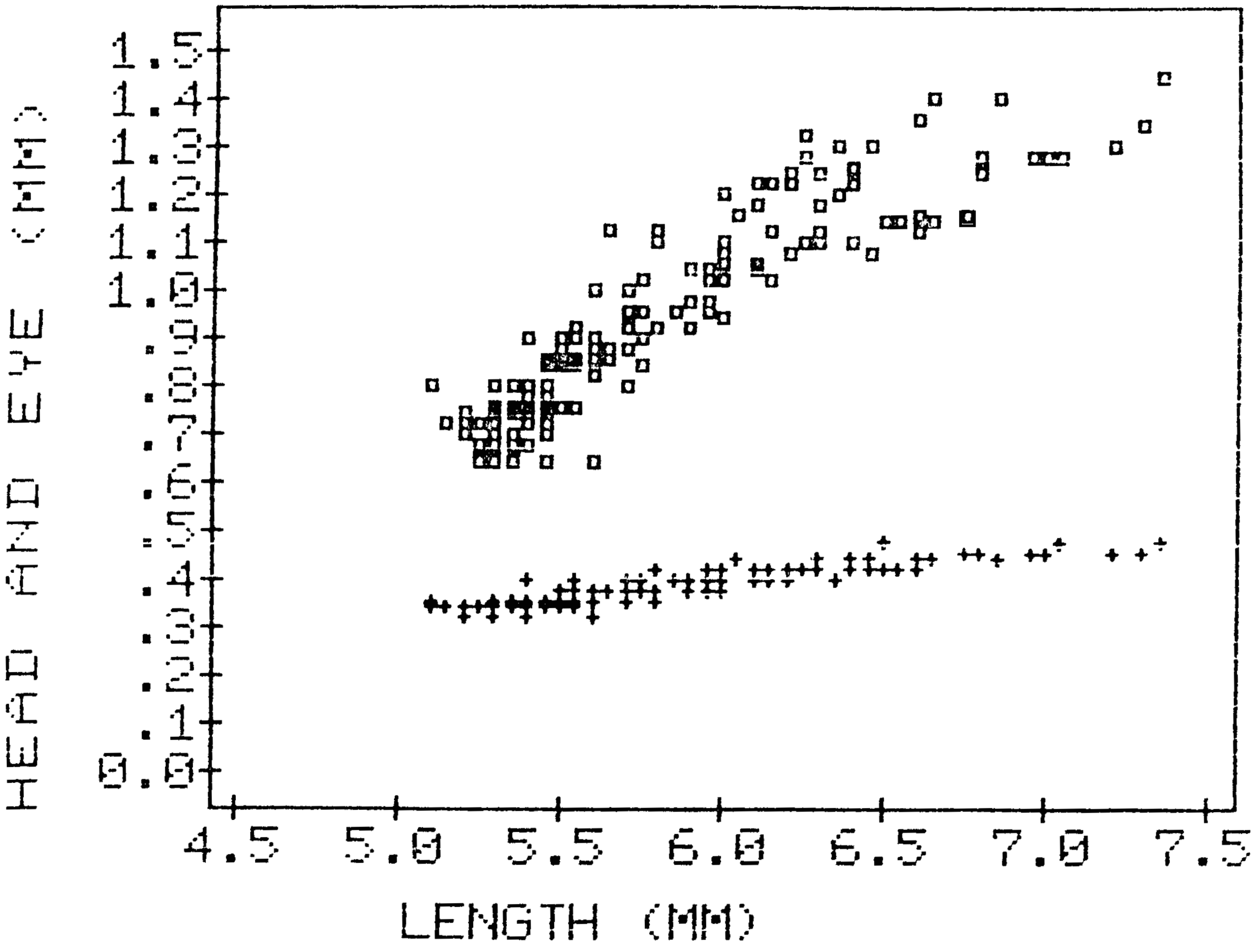

Figure 9: Survivorship of mahimahi larvae (C. hippurus) reared under various conditions. (data obtained from 15 Oct. spawn).

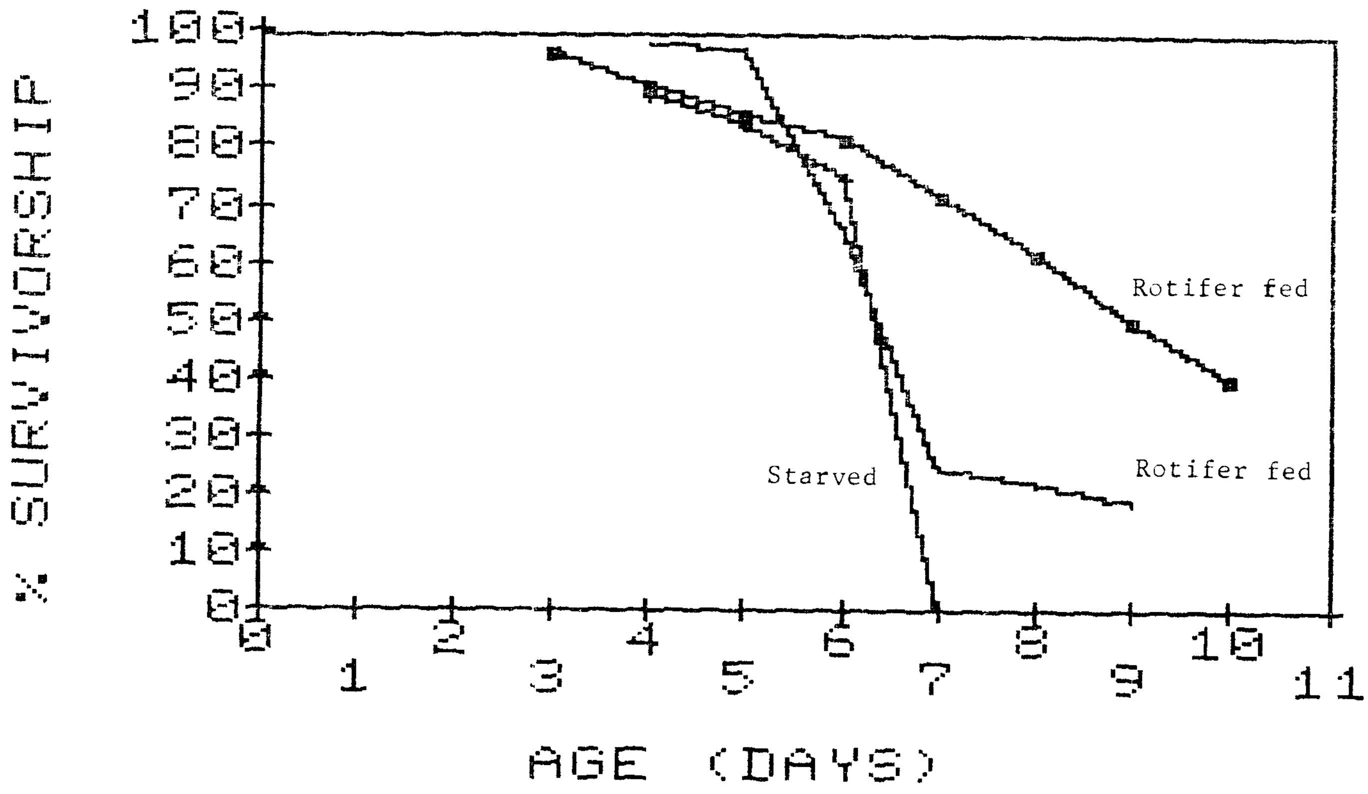

Figure 10: Food selection by skipjack tuna larvae on day 3. Comparison of the proportion of available food (P) to the ration (R).
Clear bars=nongravid rotifers,
shaded bars=gravid rotifers,
slashed bars=*Euterpina* nauplii,
stippled bars=*Euterpina* copepodites.

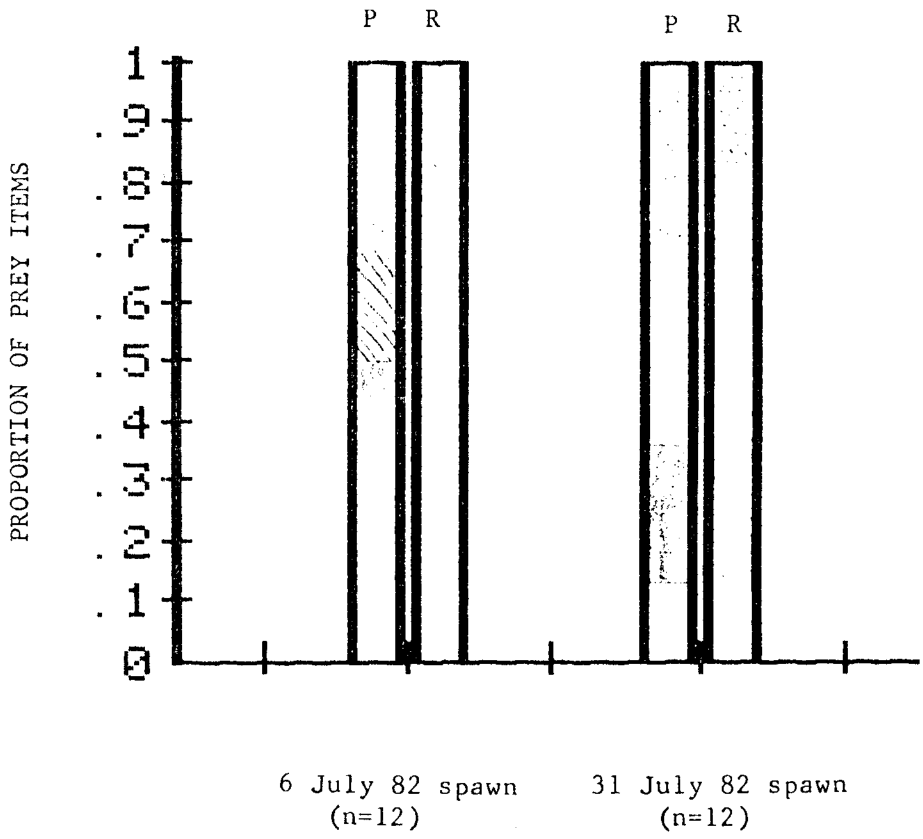

Figure 11: Food selection by mahimahi larvae (C. hippurus, 16 May 82 spawn). Comparison of the proportion of available food (P) to the ration (R). Shaded bars=Euterpina copepods, Clear bars=Euterpina nauplii , Slashed bars=rotifers.

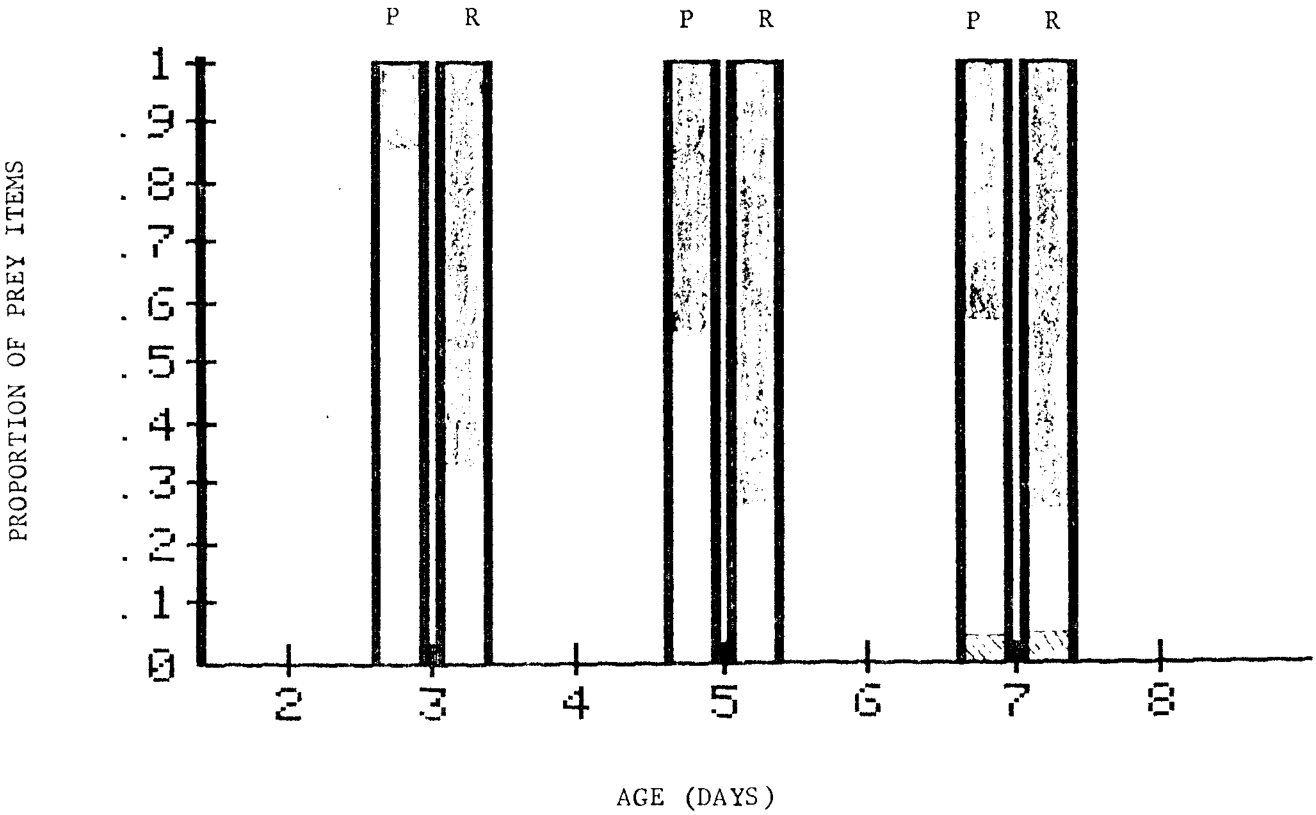

Figure 12: Food selection by mahimahi larvae (C. hippurus, 15 Oct. 82 spawn). Comparison of the proportion of available food (P) to the ration (R). Shaded bars=gravid rotifers, clear bars=nongravid rotifers.

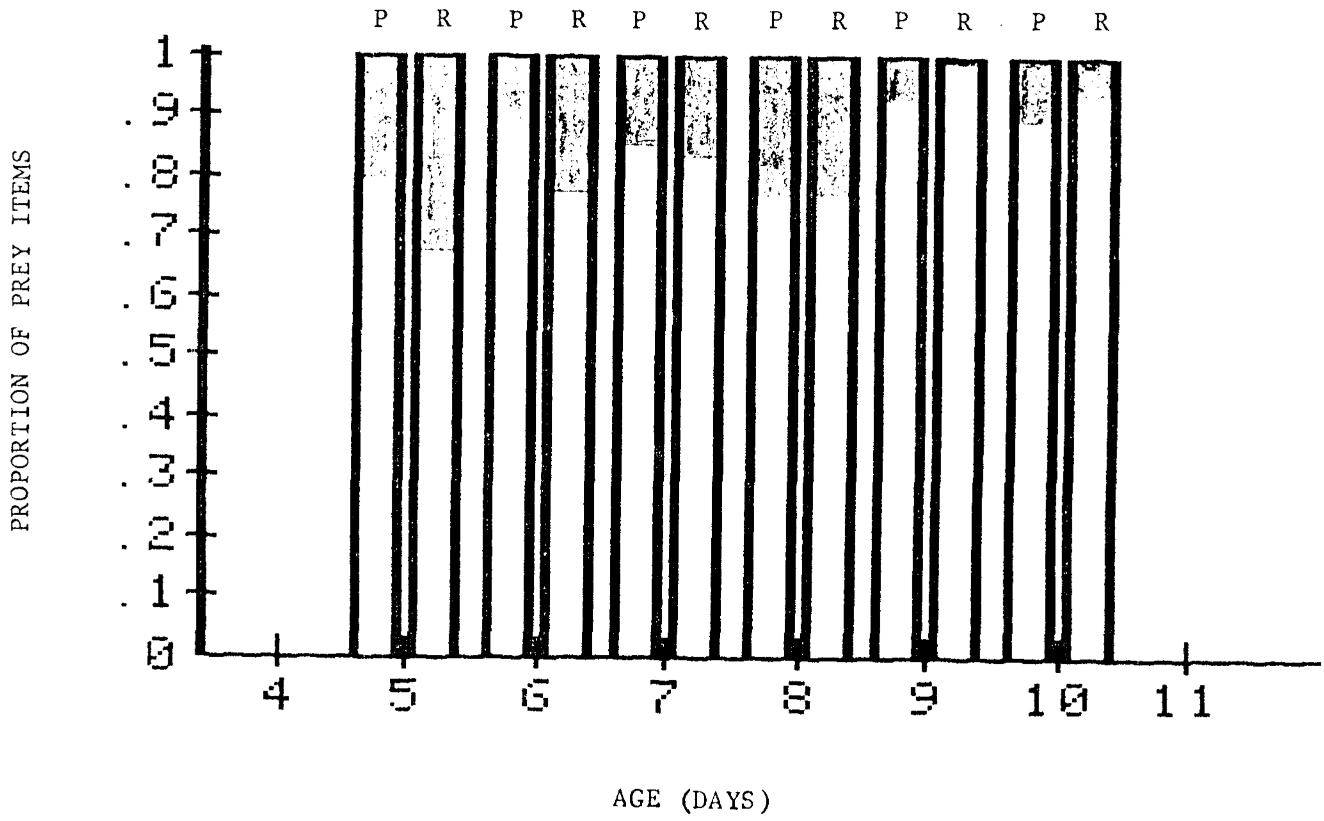

Figure 13: Feeding and swimming behavior for mahimahi larvae (C. hippurus). Mean swim speeds are given in cm/sec (□) and body lengths/sec (■). Bars represent feeding strike behavior; Shaded bars=abandoned strikes, clear bars=successful strikes (note: no data available on abandoned strikes for days 4-6). (data obtained from 15 Oct. spawn).